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LASER RADAR MEASUREMENT OF ATMOSPHERIC TEMPERATURE PROFILES.(U)
MAY 79 J A COONEY DAAG29-75-G-0101

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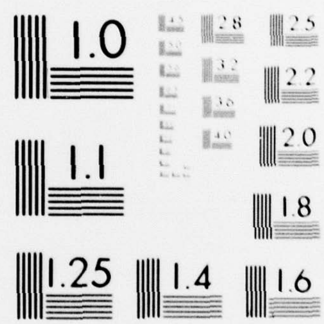
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laser radar was implemented as a raman lidar by redesigning two channels into the receiver. Thus two filters permitted two different portions of the Raman rotational spectrum of the air mix of N_2O to be monitored. A ratio of these two intensities is a unique function of the temperature.

Measurements by laser radar reproduced temperature profiles with an average absolute difference of ± 1.0°K at altitudes up to 2.3 km as compared with radiosonde profiles.

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Publications: (by Principal Investigator)

1. "Normalization of Elastic Lidar Returns by Use of Raman Rotational Back-scatter," Appl. Optics, Feb. 1975.

2. "Experimental Results of Temperature Profile Measurements," (with M. Pina), Appl. Optics, March 1976.

3. "Atmospheric Temperature Profiles from Lidar Measurements of Rotational Raman and Elastic Scattering," Appl. Opt., Nov. 1976 (with A. Cohen and K. Geller).

4. "Measurement of Atmospheric Temperature Profiles Using Raman Lidar", Jour. Appl. Met., Feb. 1979, with K. Geller, A. Cohen, R. Gill and J. Farina.

Invited Papers:

1. "The Meteorological Use of Laser Radar," 54th Annual Meeting of AMS, Honolulu, Hawaii, Jan. 1974.

2. "Prospects for the Future Application of Lidar to Important Meteorological Problems," Meteorological Society of Japan, Research Bureau of Meteorology, Sendai, Japan, Sept. 1974.

3. "Raman Laser Atmospheric Sensing," NATO Scientific Meeting, Rjuken, Norway, June 1975.

4. "Atmospheric Temperature Measurements Using Lasers," Deutche Lasieren Conferenz, Munich, W. Germany, June 1975.

5. "Atmospheric Temperature Profiles," IAMAP Symposium, Garmish-Patrischkirken, W. Germany, Aug. 1975.

Invited University Lectures

1. "Uses of Raman Spectroscopy in Remote Sensing," (Parsons Lecture), Johns Hopkins Hospital, Baltimore, MD, April 1976.

Contributed Talks

1. "Measurements of Aerosol Returns Employing Rotational Raman Scattering," 6th International Laser Radar Conference, Sendai, Japan, Sept. 1974.

2. "Measurements of Atmospheric Temperature Profiles Using Raman Rotational Backscatter," 6th International Laser Radar Conference, Sendai, Japan, Sept. 1974.

3. "Measurement of Temperature by Applications of Laser Scattering," 7th International Laser Radar Conference, Palo Alto, CA, Nov. 1975.

4. "Measurements of Atmospheric Visibility," 7th International Laser Radar Conference, Palo Alto, CA, Nov. 1975 (with A. Cohen).

5. "Correlation of Daylight Signals in Adjacent Wave Length Bands," 7th International Laser Radar Conference, Palo Alto, CA, Nov. 1975.

6. "Measurements of Water Vapor," 7th International Laser Radar Conference, Palo Alto, CA, Nov. 1975.

7. "Studies of Signal Correlation for Adjacent Optical Bands Using Lidar," IAMAP Symposium, Garmish-Patrischkirken, W. Germany, Aug. 1976.

8. "Indirect Interaction Frequency Shift," Sub-Millimeter Wave Conference, IEEE, Puerto Rico, Dec. 1976.

9. "Uses of a Submillimeter Wave Lidar," Sub-Millimeter Wave Conference, IEEE, Puerto Rico, Dec. 1976.

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Degrees Earned:

J. Pina M.S., 1975

M. Pina M.S., 1975

M. Pina Ph.D. 1977

AROD FINAL TECHNICAL REPORT

This is the final technical report of the work on GRANT DAAG29-75G0101 and covers the period April 1975 to December 1978. This scientific program has provided results to date which strongly suggest continued efforts along the same line of endeavor and so an added years of work has been scheduled. Briefly this further effort is designed to solidify the achievements to date as well as to extend the range of applicability of the device. Out of this research a so-called "6-2" program can emerge.

The program involved both field trials and supporting laboratory work. The entire effort concerned itself with the acquisition of atmospheric temperature profiles by use of laser radar (lidar). By monitoring the radiation from two so-called Raman channels, signals were acquired of the inelastic component of the backscattered radiation. This radiation derived from transitions within the pure rotational levels of the atmospheric mix of O_2 and N_2. The equilibrium distribution of these levels provides a source of an extremely precise measure of the atmospheric temperature. In particular, radiation from a ruby laser was "outputted" at 6943Å with a bandwidth of about 1.0Å. Two channels, one centered at 6916Å and the other at 6890Å, received the rotational Raman return. The temperature is obtained from a given altitude because it is uniquely related to the ratio of the radiation from these two channels at the same altitude.

The initial phase of this 3.5 year effort involved a relatively crude check of the theory of the measurement. Most of the basic theory had been published prior to the beginning of this program. The results of the first phase effort showed a good semi-quantitative check between theory and experiment.

The first year's effort began with the design and construction of an electro-optical multi-channel receiver for the lidar. The earliest field tests involved collection of the data in a sequential manner. That is to say the data from each individual Raman channel was collected on successive shots or successive groups of shots. Experience quickly ruled this out as a useful procedure and the data collection had changed to simultaneous acquisition of both channels of the Raman data.

As noted just above, the so-called sequential mode acquisition of data gave rise to results which were uninterpretable. On the other hand, the so-called simultaneous mode gave results using the oscilloscope picture method of data acquistion which had approximate agreement with radiosonde data. This agreement between lidar and radiosonde gave results of $\pm$ 5.0 K^oat about 900 meters. (See App. Opt., March 1976, p. 602.)

These preliminary experiments clearly showed that the basic ideas were sound. However, this work also made very plain the fact that large amounts of data would have to be collected in order to provide adequate statistics to narrow down the statistical uncertainties.

The next phase of the effort concerned itself with the implementation of a more automated data acquisition scheme. The lidar receiver was implemented with a transient digitizer (Biomation) and a mini-computer (Data General). As no precise preexisting design and testing information was available, this required significant software and interface design. This laborious effort took the second year as well as part of the third year.

Subsequent to the refitting of the data acquistion system, new field trials were planned and executed in the latter half of the third year. In the late summer of 1977, useful data started to become available. Data was collected on a number of occasions during the field trials in the latter half of 1977, it also started to become clear that a new, and in some ways, more intractable level of problems was being unearthed. In this series of experiments it became clear that the basic mechanical stability of the lidar frame was inadequate and the variability of the internal optical alignment was very often preventing the routine acquistion of worthwhile temperature data.

The basic lidar frame which had been built in 1970-71 while of sufficient stability to do water vapor measurements was proved to be inadequate for the significantly more stringent demands of stability of the temperature measurement.

The latter half of 1978 was used to build a more stable lidar. There is thus now available a new lidar radically redesigned and rebuilt. The extensive machine shop costs were largely defrayed by the NASA base at Wallops Island, Virginia.

Several important things have been learned during this research effort. First and foremost is that temperature profiles can be acquired by lidar with less than $\pm$ 1^{o}K difference with radiosonde data and this can be achieved at the 2.0 km level (see JAM. Feb. 1979). Secondly, use of a more advanced (but currently available) transient digitizers can greatly increase the accuracy-range for a given laser output energy. Thus, replacement of the Biomation 8100 currently used with the Tektronix 7912 can permit the acquisition of much more representative signal with which to average. This averaging is critical to statistical accuracy. The Tektronix unit is double the cost of the Biomation unit, but it acquires close to 100% of the signal as opposed to the 20% or less acquired by the Biomation. Because the atmosphere changes sufficiently on time scales corresponding to typical data taking times (2.5 hr.); this difference can be critical. Of course, technology applied in a different direction, that is in the form of much more powerful output power from the laser can achieve an equivalent result.

Finally, it has been suggested that temperature profiles valid from the ground up would have much greater utility than those which begin at 300 or 400 meters altitude. Normally, because the lidar system does not in its ordinary deployment configuration easily admit of acquiring signals at the ground, either because of incomplete transmitter receiver beam overlap or too large a signal coming from the atmosphere very close to the lidar, the first few hundred meters of signal is deliberately discarded and so the profile begins at 300 m or so. To obtain profiles from the ground up can be accomplished (short of a major lidar redesign) by "using up" the first few hundred meters with a horizontal stretch of beam path. At the end of this horizontal path, a large (about the size of the primary) mirror can then direct the beam skyward. In any future scheme in which, say, different directions might want probing, such a steering mechanism would find easy applicability anyway.

Any immediate future effort on this program will be designed to obtain more precise data on the accuracy of the lidar profiles than can be provided by the comparisons with radiosondes. This effort will be accompanied by attempts to provide considerable extension of range.